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Increasing water resources availability under climate change

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Abstract

The attention to the water scarcity problems caused by climate change is paid in the Czech Republic since 1990´s. Increasing daily mean temperature, changes in distribution of precipitation and earlier snow melt lead to insufficient recharge of the groundwater reserves and in turn to a decrease of baseflow component of total runoff. Water streams are then more sensitive to drying during dry periods, which has far-reaching impacts on water stream ecology and the availability of water for the users.
The paper describes objectives, methods and first year results of the project 'Increasing water resources availability in selected regions of Karlovy Vary district'. The project is focused on the region that faces long term problems with water availability. The objective is a development and verification of methods for proposal of adaptation measures to increase the reliability of water resources in the periods of water stress.

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Keywords: climate change; adaptation measures; water resources; watre use

1. Introduction

Results of modelling of water balance in the last decades show that global climate change and climate variability alter hydrological conditions in some catchments relatively rapidly. The number of projects in the T. G. Masaryk

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Water Research Institute (TGM WRI) concerning climate change confirms this trend. The first studies in the Czech Republic on focusing on climate change impacts were probably carried out there already in 1992. Over the years, increasing emphasis has been put on the topics directly related to the climate change as hydrological modelling, adaptation measures to climate change, climate change scenarios etc. The most important study from the last years are: Spatial and temporal variability of hydrological drought under the climate change conditions over the Czech Republic [1], Climate change impacts on the hydrological regime in the Czech Republic and possible adaptation measures [2, 3], Guidance for proposal of adaptation measures to eliminate the impacts of climate change on hydrological balance in the Czech Republic [4], Landscape strategy protection against negative impacts of floods and erosion processes using actions in consistent with nature in the Czech Republic [5].

The paper presents the first year results of the project “Increasing water resources availability in selected regions of Karlovy Vary district”. This project continues the research on identified problems with water availability in the region of the Czech Republic following from project “Prospective study of water needs and sources in Karlovy Vary region” [6]. The main problem for the water management in the Czech Republic is the location of the country. Water resources are closely related to the amount of total precipitation and to the water reservoirs in the basins. There are no more water sources, all of the surface water flowing of to the North Sea (Labe basin), the Baltic Sea (Odra basin) and the Black Sea (Morava basin). The actual project tries to develop guidance for proposals of adaptation measures leading to increasing reliability of water resources in the periods of water stress using existing infrastructures as much as possible.

2. Methodology

The location of the Karlovy Vary district is given in Figure 1. The study area is divided into eleven catchments that are located over the district. For each catchment individual water balance components (temperature, precipitation, potential evapotranspiration, evapotranspiration, runoff) were assessed. Precipitation, air temperature and the amount of runoff were available from the database of the Czech Hydrometeorological Institute for the past and present time periods 1961-1990 and 1981-2010.

Water balance components of catchments in monthly step were assessed by hydrological model Bilan [7], [8]. The model simulates water budget at three vertical levels: on the ground, in the aeration zone of the soil including the effect of vegetation cover, and in the groundwater zone. Water balance algorithms that are applied are developed for winter conditions, snow melting and summer conditions. Surface water balance depends on the evapotranspiration, which is derived for individual months and for different climatic zones considering temperature and relative air humidity [9] or is estimated using a relationship derived by [10], employing solar radiation and air temperature. Excess water forms direct runoff or infiltrates to deeper zone, where it is divided into interflow and groundwater recharge. The input data used for water balance computation include the daily or monthly series of basin precipitation, air temperature and relative air humidity (optional). Parameters of the model are determined by two-step optimization base on the deviations between observed and simulated runoff. The model makes use of eight (monthly time step) free parameters for the calibration (Table 1). The optimisation is aimed at attaining the best fit between the observed and simulated runoff series, for which several optimisation criteria are available.

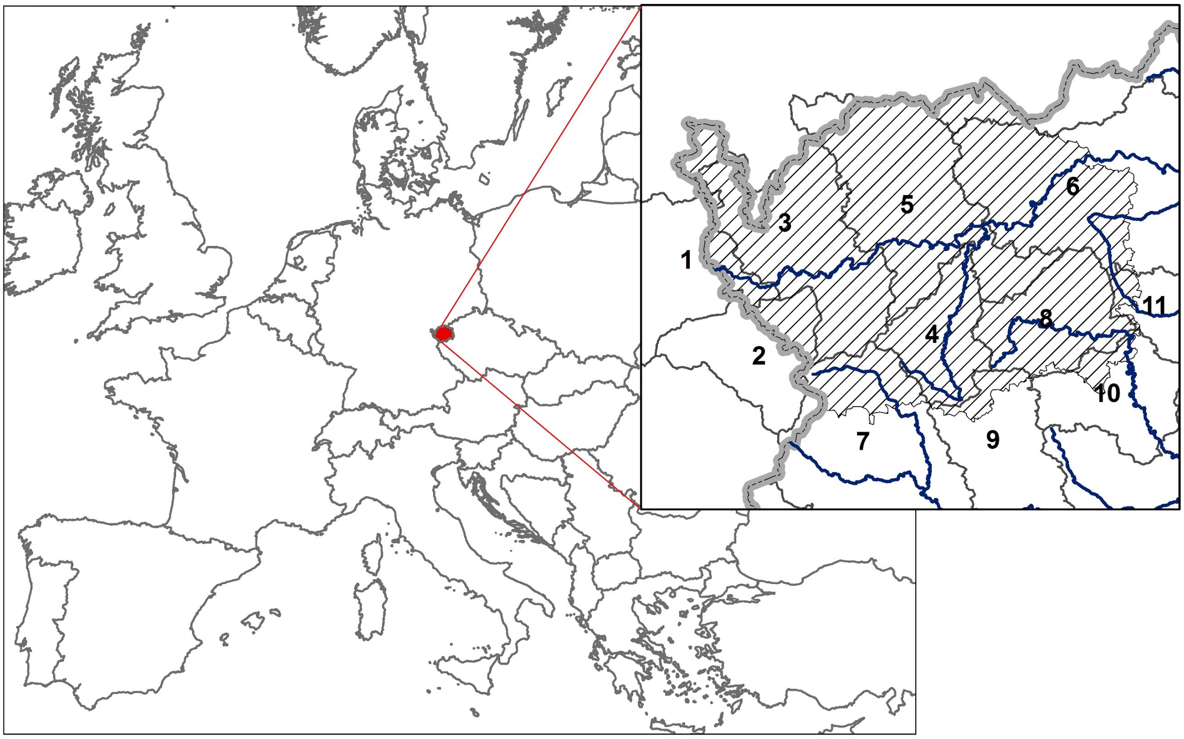

Fig. 1. Study area with numbered catchments.

Table 1. Parameters of monthly Bilan model.

Spa	Capacity of soil moisture storage [mm]
Dgm	Temperature/snow melting factor
Dgw	Factor for calculating the quantity of liquid water available on the land surface under winter conditions
Alf	Parameter of rainfall-runoff equation (direct runoff)
Soc	Parameter controlling distribution of percolation into interflow and groundwater recharge under summer conditions
Mec	Parameter controlling distribution of percolation into interflow and groundwater recharge under conditions of snow melting
Wic	Parameter controlling distribution of percolation into interflow and groundwater recharge under winter conditions
Grd	Parameter controlling outflow from groundwater storage (baseflow)

Future periods 2021-2050 and 2071-2099 were considered for climate change assessment. For modelling of the climate change impacts on the basin hydrological balance, we consider 15 transient Regional Climate Model (RCM) simulations (Table 2) all covering period 1961-2099. All simulations were forced by the global climate model simulations under SRES (Special Report on Emissions Scenarios; [11]) A1B emission scenario and have horizontal resolution of 25 x 25 km. Most of the simulations (14) were conducted within the Ensembles project. The CHMI_ARP simulation was produced by the Czech Hydrometeorological Institute.

Table 2. Overview of the RCM simulations.

Acronym	RCM	Period available	Source
ECHAM5 driven			1 Royal Netherlands Meteorological Institute (KNMI) 2 Max Planck Institute for Meteorology (MPI), Germany 3 Swedish Meteorological and Hydrological Institute (SMHI) 4 Abdus Salam International Centre for Theoretical Physics (ICTP), Italy 5 Danish Meteorological Institute (DMI) 6 Met Office Hadley Centre, UK 7 Swiss Federal Institute of Technology Zurich (ETHZ) 8 Community Climate Change Consortium for Ireland (C4I) 9 National Centre of Meteorological Research (CNRM), France 10 Czech Hydrometeorological Institute (CHMI), Czech Republic
RACMO_EH5 1	RACMO2.1	1950–2100	
REMO_EH5 2	REMO5.7	1951–2100	
RCA_EH5 3	RCA3.0	1951–2100	
RegCM_EH5 4	RegCM3	1951–2100	
HIR_EH5 5	HIRHAM5	1951–2100	
HadCM3Q0, HadCM3Q3, HadCM3Q16 driven			
HadRM_Q0 6	HadRM3.0	1951–2099	
CLM_Q0 7	CLM2.4.6	1951–2099	
HadRM_Q3 6	HadRM3.0	1951–2099	
RCA_Q3 3	RCA3.0	1951–2099	
HadRM_Q16 6	HadRM3.0	1951–2099	
RCA_Q16 8	RCA3.0	1951–2099	
ARPEGE4.5 driven			
HIR_ARP 5	HIRHAM5	1951–2100	
CNRM5_ARP 9	CNRM-RM5.1	1951–2100	
CHMI_ARP 10	ALADIN-CLIMATE/CZ	1961–2100	
BCM2.0 driven			
RCA_BCM 3	RCA3.0	1961–2100	

3. Results

3.1. Study area

Karlovy Vary (KV) district is located in the western tip of the Czech Republic. It has 3314 km2 which is 4 % of the area of whole country. The northern part of the KV district occupies the Ore Mountains with the highest peak Klínovec (1244 m above sea level). The south part is occupied by upland of Slavkov Forest (Lesný 983 m above sea level) and Doupov Mountains (Hradiště 934 m above sea level). The KV district is divided in the middle from west to east by river Ohře, with the main tributary rivers Teplá, Rolava and Svatava. The Ohře basin belongs to the Labe basin with drainage area of the North Sea.

Table 3 shows individual hydrological components observed and modelled by BILAN. In the seasonal distribution of the total runoff there are significant climate change impacts and both future periods show similar trends. For the seasonal distribution of total runoff significant increase during winter months, significant decrease during spring and summer months and not-significant changes during autumn are typically projected. Total runoff during winter for future period 2021-2050 is expected to vary from +10 to +25 %, during spring months from -13 to -1 %, during spring from -5 to +8 % and during autumn months from -1 to +7 %. For further period 2071-2099 changes in winter runoff are from +10 to +31 %, in spring months from -26 to +6 %, in summer from -30 to -9 % and for autumn from -26 to -1 %. Figure 2 shows relative seasonal change in the river runoff of modelled catchment.

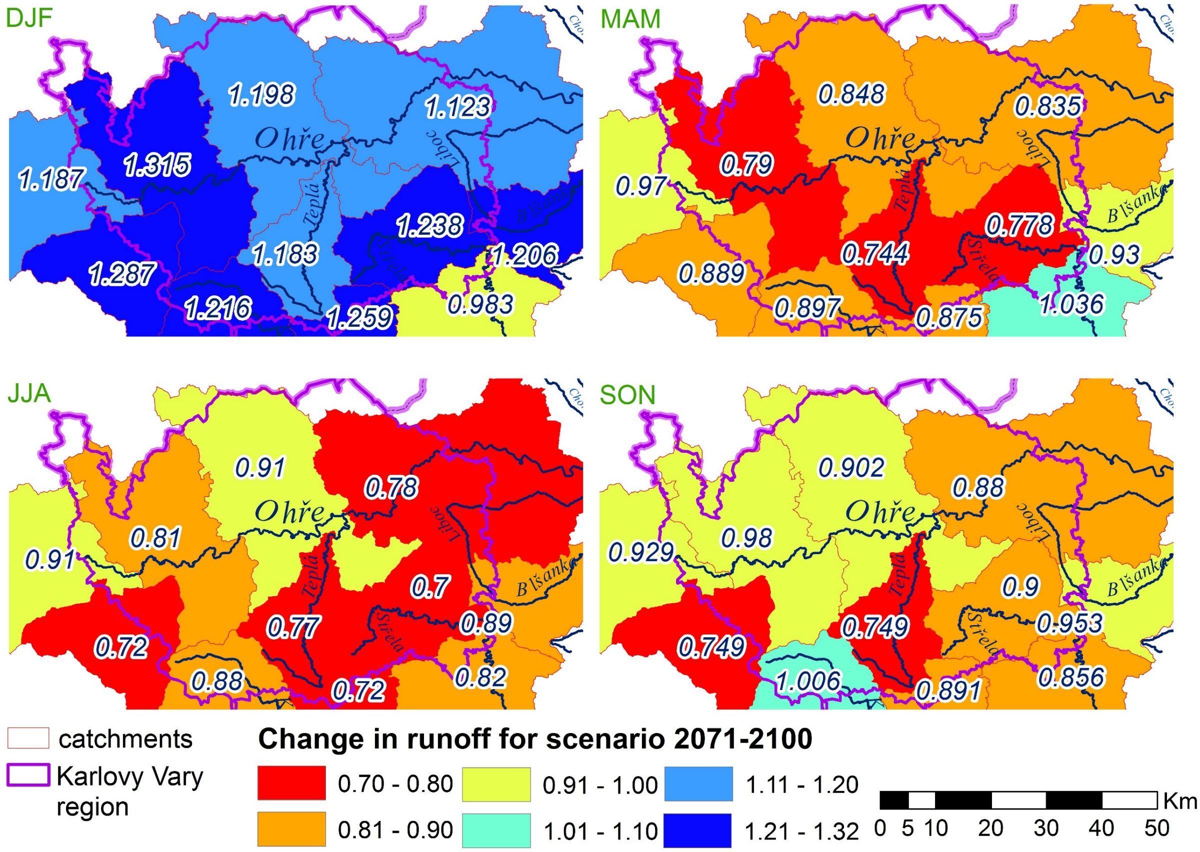

Fig. 2. Relative seasonal changes in the total runoff on the individual catchments for 2071-2099.

Table 3. Basic climatic and hydrologic components of the individual catchments.

Catchment (river location)	Air temperature [°C]		Precipitation [mm/year]		Pot. evapotranspiration [mm/year]		Evapotranspiration [mm/year]		Total runoff [mm/year]	
	1961-1990	1981-2010	1961-1990	1981-2010	1961-1990	1981-2010	1961-1990	1981-2010	1961-1990	1981-2010
1 Ohře Cheb	6.6	7.1	795	833	529	552	474	501	319	328
2 Odrava Jesenice	6.5	7.1	706	741	526	549	491	514	214	224
3 Ohře Citice	6.5	7.1	687	734	527	549	446	467	241	264
4 Teplá Březová	5.8	6.2	690	751	501	518	473	493	217	255
5 Ohře Karlovy Vary	6.1	6.6	742	822	509	531	436	460	305	359
6 Ohře Žatec most	6.9	7.5	614	656	542	566	475	494	140	159
7 Mže Stříbro	6.7	7.2	642	682	536	556	445	462	197	217
8 Střela Čichořice	6.2	6.7	601	619	518	538	441	454	161	164
9 Mže Hracholusky	6.7	7.2	560	590	534	556	445	464	115	125

10 Střela Plasy	6.9	7.5	528	546	543	567	458	477	72	66
11 Blšanka Holedeč	7.6	8.2	495	515	569	594	445	465	52	49

3.2. Identified threats and suggested adaptation measures

The choice of the case localities facing long term problems with water availability was based on the recommendation of Povodí Ohře (River basin authority) and also followed results of previous research.

Within present climatic conditions and taking into account present rules of water management and preservation of the minimal flows, there is passive water balance in the profile below the Březová dam. The Březová dam is the main water treatment facility and strategic source of drinking water for city of Karlovy Vary and other cities in the surroundings. There are two proposed measures increasing reliability of this water resource. The first possible adaptation measure consists of water transfer from a close profile of river Ohře, where the minimal flows are secured. This measure was assessed in detail by modelling of the whole water management system of the district. It was confirmed that the transfer would help to ensure water supply by the dam Březová in the dry periods. Second proposed measure takes advantage of the list of localities potentially suitable for accumulation of surface water (LASW) in the Czech Republic. The list exists from the beginning of the 20th century and currently mentions 65 localities (it was more than 400 in the past). The list of LASW is being updated within the project “Compensation of negative climate change impacts on water supply and ecosystems using the localities for potential accumulation of surface water” and was described in [12].

Within future period (next 50 years) influenced by climate change the minimal flows are not sufficiently secured in the profiles of leftward tributaries of the Ohře river especially Svatava and Rolava. However, the available exact information on the actual conditions in their catchments is limited. Therefore the proposal is to densify the limnigraphic stations network in order to refine the assessment of the water use impacts on catchments.

Long term problems with water supply are in the area around the city of Kraslice. There is no public water supply and people have to draw water from the groundwater supply. That problem is being partly solved by bringing water pipeline from Germany (city of Klingenthal). Further optimization is also challenge for the present project.

4. Conclusions

The paper summarizes first year results of a project “Increasing water resources availability in selected regions of Karlovy Vary district” which is solved by T. G. Masaryk Water Research Institute, p.r.i.. The main goal of the project is to create a methodology for proposals leading to secure water demand in the dry periods with an emphasis on the maximal use of an existing infrastructure. The project builds on the results of previous project “Prospective study of water needs and sources in Karlovy Vary region” from the 2010.

In the first year it was to create a database of hydrological, meteorological and of water use data which will be used to model water management system of the Ohře basin. Model will be testing the set of proposal adaptation measures to ensure water demand in the present period and in the future time period under climate change conditions as well.

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